Evaluation of Photic Countermeasures for Circadian Entrainment of Neurobehavioral Performance and Sleep-Wake Regulation Before and During Spaceflight

Completed Technology Project (2008 - 2012)

Project Introduction

To synchronize astronauts' circadian sleep-wake schedules to variable launch times, timed exposure to bright light and darkness in the crew quarters during the week-long pre-launch quarantine period has been used since 1990. Although successful at circadian entrainment, bright light protocols are complex to administer and astronauts' compliance is compromised because bright light glare compromises screen visibility, and increases frequency of headaches, irritability, and nausea. Moreover, bright light remains unavailable as an in-flight countermeasure, requiring astronauts to rely upon hypnotics or wake-promoting therapeutics to provide symptomatic relief. Recent advances reveal that the human circadian pacemaker is most sensitive to shorter wavelength light for both phase shifting and direct enhancement of alertness and performance. We therefore proposed to test the efficacy of exposure to short wavelength green light at a standard intensity for pre-launch and in-flight phase shifting.

To this end, we examined the circadian phase-shifting efficacy of exposure to short wavelength light throughout scheduled wake times on a protocol designed to simulate the schedule of crew members during the pre-launch quarantine period on a mission that requires an 8h phase advance of the sleep-wake schedule. Our goal was to demonstrate that exposure to ambient short wavelength fluorescent light would synchronize human circadian rhythms to a shifted sleep/wake schedule within 4-5 days, enhancing alertness and performance during the biological night.

During this proposed simulation sleep-wake schedules were advanced by 8h using 3 different schedule protocol designs: 1) a "slam" shift in which the sleep episode was abruptly advanced by 8h and then maintained for 4 days, 2) a gradual shift in which the sleep episode was advanced by 1.6h each day for 5 days until an 8h advance was achieved, and 3) a slam shift with naps in which the extended wake period prior to the 8h advance of the sleep period included 2 short nap opportunities. Given the prolonged extended wake period on the second day of the slam shift schedule, the new schedule involved the opportunity to obtain two short naps: one for 2h during the afternoon circadian dip, and the second for 4h at the circadian nadir during the night. A total of 43 participants were studied in the project. They were randomized to 1 of 5 protocol conditions which differed by light and by shift schedule. The 5 conditions were 1) white light slam shift, 2) green light slam shift, 3) combined white + green light slam shift with naps, 4) white light gradual shift, and 5) green light gradual shift.

Our specific aims were to test the hypotheses that: 1. Exposure to ambient polychromatic green light would be more effective than exposure to an equal illuminance of polychromatic white in shifting circadian rhythms, as measured by dim-light melatonin onset (DLMO), in response to both a gradual 8h advance and to an abrupt shift of their sleep-wake schedule. 2. Alertness and

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Table of Contents

neurobehavioral performance in dim light on a constant routine (CR) during times at which crew members should be awake on the simulated mission would be significantly greater following 4-5 days of exposure to ambient polychromatic green light vs. ambient white light of equal illuminance, due to more effective circadian entrainment. 3. Alertness and neurobehavioral performance would be significantly better on the first night of exposure to ambient polychromatic short wavelength light vs. ambient white light of equal illuminance, prior to the induced circadian phase shifts, due to the immediate alerting effects of exposure to ambient polychromatic short wavelength light. 4. Sleep efficiency and total sleep time would be significantly increased and latency to persistent sleep and wake time after sleep onset would be significantly decreased during the sleep episode following 4-5 days of exposure to ambient polychromatic green light vs. ambient white light of equal illuminance, due to more effective circadian entrainment.

We predicted that exposure to polychromatic green light throughout the day would rapidly entrain the circadian melatonin rhythm to the shifted sleep-wake schedule. We also predicted that green light combined with brighter white to prevent the altered color-perception from the green light alone would enable implementation of this new technology to ensure circadian synchronization both during the pre-flight quarantine period and while aboard NASA flight vehicles. We predicted that our new schedule with naps would reduce the excessive daytime sleepiness and other adverse effects often experienced with the slam shift due to prolonged wakefulness. As per a supplemental grant (HPF00003), we implemented novel infra-red reflectance oculography technology into this protocol to detect fatigue, and collected data on eye movements in n=30 participants during periods of extended wake. New eye tracking technologies were implemented into the protocol, in order to examine causes of neurobehavioral deficits during periods of extended wake.

Anticipated Benefits

We implemented and tested a new polychromatic fluorescent lamp with a peak spectral sensitivity of ~500 nm. This is near the peak sensitivity of the human circadian system, and thus should be the most efficacious polychromatic lamp for shifting the timing of the human biological clock. In addition to benefits for NASA flight personnel this technology will also have application to shift-workers, to jet travelers, and to any personnel who need to shift the timing of their biological rhythms.

Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Organization:

National Space Biomedical Research Institute (NSBRI)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Principal Investigator:

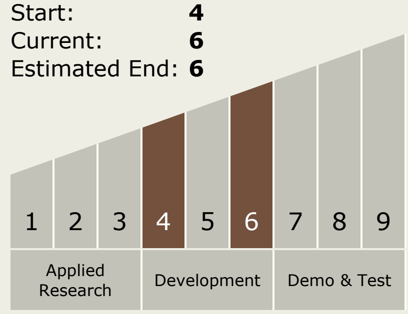
Charles A Czeisler

Co-Investigators:

Laura K Barger
Daniel Aeschbach

Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



Evaluation of Photic Countermeasures for Circadian Entrainment of Neurobehavioral Performance and Sleep-Wake Regulation Before and During Spaceflight

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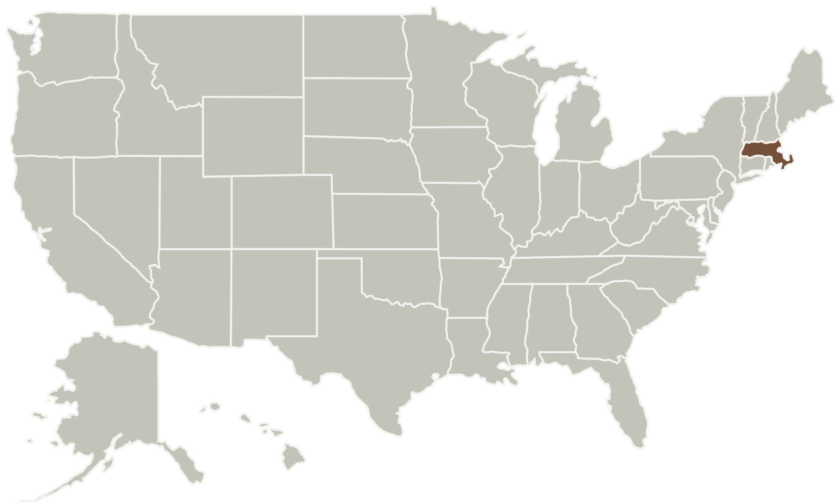
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
National Space Biomedical Research Institute(NSBRI)	Lead Organization	Industry	Houston, Texas
Brigham And Women's Hospital, Inc.	Supporting Organization	Industry	Boston, Massachusetts

Primary U.S. Work Locations
Massachusetts

Project Transitions

May 2008: Project Start

Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - └ TX06.3 Human Health and Performance
    - └ TX06.3.2 Prevention and Countermeasures

Target Destinations

The Moon, Mars

September 2012: Closed out

Closeout Summary: In the last year we completed our in-patient studies ahead of schedule. We also implemented novel i nfra-red reflectance oculography technology into this protocol for detecting fatigue, and collected data on eye movements i n n=30 participants during periods of extended wake. We have completed analysis of melatonin assay results, and are conti nuing analysis of sleep, alertness, performance testing, and eye movement data; we also are preparing manuscripts of resu lts.

Stories

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/60591)

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/60574)

Abstracts for Journals and Proceedings
(https://techport.nasa.gov/file/60572)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/60589)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/60575)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/60605)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/60570)

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Project Website:

https://taskbook.nasaprs.com